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USER
GUIDE

Corrosion Control Acceptance Criteria for Sacrificial Anode Type, Cathodic Protection Systems

by
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Innovative Ideas for the Operation, Maintenance, & Repair of Army Facilities

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CORROSION CONTROL ACCEPTANCE CRITERIA FOR SACRIFICIAL ANODE TYPE, CATHODIC PROTECTION SYSTEMS

1 EXECUTIVE SUMMARY

Background

The Army currently operates and maintains more than 20,000 underground storage tanks and over 3000 miles of underground gas pipelines, all of which require some form of corrosion control. Cathodic protection is one method of corrosion control used to prevent corrosion-induced leaks when a steel structure is exposed to an aggressive soil. Before accepting a cathodic protection (CP) system, the Directorate of Engineering and Housing/Directorate of Public Works (DEH/DPW) reviews the performance check data as supplied by the engineering firm that installs the CP system. A performance check after installation is usually called for in the plans and specifications. The CP system performance data may show problem areas not readily identified in the original design or construction phases. Even properly designed and specified CP systems cannot be expected to function properly unless the proper materials are delivered to the job site and are subsequently installed in accordance with the design and installation specifications. If a performance check is not properly done, the DEH/DPW may be forced to accept a CP system that may not provide adequate cathodic protection to the steel structure.

The corrosion control acceptance criteria for sacrificial anode type CP systems provides guidelines for the DEH/DPW cathodic protection installation inspectors whose responsibilities are to ensure that the materials and equipment specified are delivered to the job site and subsequently installed in accordance with the engineering drawings and specifications. The sacrificial anode CP acceptance criteria includes all components for the sacrificial anode system such as insulated conductors, anodes, anode backfills, and auxiliary equipment. The sacrificial anode CP acceptance criteria is composed of a checklist that lists each component and that contains a space for the inspector to either check "yes" or "no" to indicate whether the component complies with the job specifications. In some cases, the inspector must measure and record physical dimensions or electrical output and compare the measurements to standards shown in attached tables.

The use of sacrificial anode CP acceptance criteria will reduce the costs associated with the premature failure of an installed (usually buried or submerged) CP system component due to improper materials selection or installation. If acceptance criteria are not followed, an entire CP system may require replacement due to incorrect installation of an anode or anode lead wire. For example, the average cost of a sacrificial anode type CP system for a typical underground storage tank system (up to six tanks) is $5 to 10K. Sacrificial systems are typically used when the current requirement is less than 1 Amp, the soil resistivity is less than 10,000 ohm-cm, or when the structure is well coated. In addition, using the sacrifical anode CP acceptance criteria can help a DEH/DPW avoid the corrosion damage and high repair and replacement cost of the structure.

The sacrificial anode CP acceptance criteria was developed and tested on a replacement CP system for gas lines at Fort Hood, TX, and on an underground fuel storage tank at Fort Lee, VA.

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2 PRE-ACQUISITION

Description of the Technology

Before actual installation, the DEH/DPW inspector must review the engineering drawings for the CP system, study the specifications for the components and materials to be used, and become familiar with the installation procedures identified in the engineering drawings and specifications.

For a CP system to function properly, the structure to be cathodically protected must be electrically continuous. Otherwise, some areas of the structure may not receive protective current. It is sometimes necessary to install metallic bonds to ensure electrical continuity. For example, it is generally necessary to install a continuity bond between each joint on bell-and-spigot, ductile-iron waterlines to achieve the required electrical continuity for the entire structure. Section 1.2 of the Appendix provides the checklist concerning electrical continuity that the DEH/DPW inspector is to complete.

Also, it is important that the structure to be cathodically protected be electrically isolated from other underground or submerged, metallic structures that might exist in the general area. Otherwise, the shorted structure(s) will receive some of the protective current and the intended structure may not be adequately protected by the sacrificial anodes. For example, shorted flanges often allow underground gas and water lines to become electrically continuous with the casings and conduits on underground, heat-distribution systems which, in turn, adversely affects the cathodic protection of the casings and conduits. Section 1.3 of the Appendix to this guide provides the checklist concerning electrical isolation that the DEH/DPW inspector is to complete.

The components and materials needed for the CP system should also be inspected. Section 1.4 of the Appendix contains the appropriate checklist on components and materials.

During the installation of the CP system, the inspector should fill out the checklist contained in Section 1.5 of the Appendix.

When the CP system is installed and ready for operation, it is necessary to ensure that additional criteria are met. Some time is normally required for polarization to take place on the structure surface. Generally, cathodic polarization is indicated by a change in the potential of a structure with respect to a reference electrode. After energizing the system, anode current output measurements should be checked immediately and monthly thereafter, and structure-to-environment potential surveys should be made annually. During commissioning of the CP system, the inspector should follow the checklist in Section 1.6 of the Appendix.

Life-Cycle Costs and Benefits

The use of acceptance criteria for impressed current CP systems used on water tanks will reduce the costs associated with the replacement of installed (usually submerged) CP system components that fail prematurally due to improper materials selection or installation. In some cases, an incorrectly installed CP component (an anode or anode lead wire) could cause the replacement of the entire CP system. The average cost of a sacrificial anode type CP system for a typical underground storage tank system (up to 6 tanks) is $5 to 10K. In addition, using the sacrifical anode CP acceptance criteria allows DEHs/DPWs to avoid the cost of corrosion damage and repair or replacement of the structure.

3 ACQUISITION/PROCUREMENT

Potential Funding Sources

DEHs/DPWs do not need to seek outside funding to use this technology. The "Acceptance Criteria for Sacrificial Anode Type Cathodic Protection Systems: An Inspector's Guide/Checklist for Components and Their Installation" is provided free of charge to Army installations.

Technology Components and Sources

The sacrificial anode CP acceptance criteria checklist can be filled out by any qualified DEH/DPW inspector.

Procurement Documents

The Corps of Engineers Guide Specifications (CEGS) 16640, "Cathodic Protection System (Sacrificial Anode, 12/88 or latest revision)" should be followed when the CP system is being designed and installed. The CP system should follow the guidance contained in TM 5-811-7, "Electrical Design, Cathodic Protection." A USACERL draft Technical Report, *Cathodic Protection Acceptance Criteria: A Guide for Directorate of Engineering and Housing (DEH) Inspectors* should be reviewed for a more in depth look at CP systems and the needed emphasis for acceptance criteria.

Procurement Scheduling

Procurement scheduling should include an Army post DEH/DPW staff planning for one or more of its members to become qualified to complete the acceptance criteria checklist. DEH/DPW personnel can become qualified inspectors by attending the *Facilities Engineering Corrosion Course* taught at USACERL in April or May of each year. Although attendance of the Corrosion Course is not required of the inspectors, it is highly recommended. Other training sources are PROSPECT course No. 009, *Corrosion Control* and National Association of Corrosion Engineers (NACE) weeklong courses, *Cathodic Protection—An Introduction* and *Cathodic Protection—Theory and Data Interpretation.*

4 POST-ACQUISITION

Initial Implementation

The sacrificial anode CP acceptance criteria inspections need to be performed in three stages. First, the materials and supplies for the CP system should be inspected when they arrive. Second, an inspection should take place during the installation of the CP system. Third, a final inspection needs to be done 2 months after the system has been in operation.

Operation and Maintenance of the Technology

The sacrificial anode CP acceptance criteria checklist is filled out by a qualified DEH/DPW inspector. There is no maintenance involved in this technology.

Service and Support Requirements

The acceptance criteria recommends that a qualified DEH/DPW inspector fill out the checklist. The DEH/DPW inspector needs to attend a USEHSC-sponsored *Facilities Engineering Corrosion Course* held at USACERL in the spring or early summer to become qualified. There is no tuition charge for the 1-week course for Department of Defense (DOD) personnel. Other training sources are listed in "Procurement Scheduling" (p 6).

Performance Monitoring

The performance of the sacrificial anode CP acceptance criteria can be measured by comparing results from the checklist with the actual performance of the CP system. A favorable performance would include a good correspondence between the evaluation and the system's performance, in other words, a properly working CP system with most of the criteria for acceptance met, or a malfunctioning CP system with few of the criteria for acceptance met.

APPENDIX: Acceptance Criteria for Sacrificial Anode Type, Cathodic Protection Systems

This appendix contains the checklist for the DEH/DPW inspector to use when a sacrificial anode type CP system is to be installed. Some questions may not be applicable for all sacrificial anode type applications.

1.0 Introduction

The components and materials for a sacrificial anode type, CP system (e.g., the insulated conductors, anodes, anode backfill, test stations, and ancillary equipment) and their installation must be properly specified and detailed on engineering drawings. Equally important, the specified components and materials must be delivered to the job site; these must be installed in accordance with the specifications and engineering drawings. Otherwise, the CP system installed may not achieve its intended objective of mitigating corrosion.

This guide and checklist can help the inspector ensure and document that the specified materials are delivered to the job site and installed in accordance with the specifications and engineering drawings.

1.1 General

Before actual installation, the inspector must review the engineering drawings for the CP system, study the specifications for the components and materials to be used, and become familiar with the installation procedures identified in the engineering drawings and specifications.

1.2 Electrical Continuity

The structure to be cathodically protected must be electrically continuous; otherwise, some areas of the structure may not receive protective current. It is sometimes necessary to install metallic bonds to ensure electrical continuity. For example, it is generally necessary to install a continuity bond between each joint on bell-and-spigot, ductile-iron, water lines to achieve the required electrical continuity for the entire structure. A typical method for obtaining electrical continuity at a high-resistance or insulated joint is shown in Figure A1.*

With regards to electrical continuity, the inspector should record answers to the following questions:

		YES	NO	N/A
1.	Were electrical-continuity bonds included in the specifications or engineering drawings?	___	___	___
	If the answer is "no," no additional questions need to be answered in Section 1.2. Proceed to Section 1.3.			
2.	If electrical-continuity bonds were required, were these installed at the locations identified in the specifications or engineering drawings?	___	___	___
3.	Were tests conducted to ensure that the continuity bonds were providing the desired electrical continuity?	___	___	___

*All Figures and Tables are located at the end of this Appendix.

	YES	NO	N/A
4. Did the copper conductor for the electrical-continuity bonds have the specified number of strands?	___	___	___

Number of Strands: ______________________________

5. What was the diameter of the copper conductor or the diameter of each strand of the size specified for the electrical-continuity bonds? Using Table A1, what was the conductor size?

Diameter of Conductor: ______________________________

Diameter of Each Strand: ______________________________

Conductor Size: ______________________________

6. What was the type and thickness of the insulation for the copper conductor used to make the continuity bonds?

Insulation Type: ______________________________

Insulation Thickness: ______________________________

	YES	NO	N/A
7. Was the insulation type and thickness in accordance with the specifications and engineering drawings?	___	___	___
8. Did each electrical-continuity bond have the required "slack" over its length to ensure that it would not be broken during backfilling or other movement?	___	___	___

9. How were the copper conductors for the electrical-continuity bonds attached to the structure?

Exothermically Welded: ______________________________

Welded: ______________________________

Brazed: ______________________________

Other; Identify: ______________________________

10. If the copper conductors for the electrical-continuity bonds were exothermically welded to the structure, what was the mold part number and the weld-metal number used?

Mold Part Number: ______________________________

Weld-Metal Part Number: ______________________________

	YES	NO	N/A
11. Were the weld-metal part number and the mold part number used to attach the copper conductors for the electrical-continuity bonds to the structure in accordance with the manufacturer's recommendations?	___	___	___
12. Was each copper conductor connection on the electrical-continuity bonds tested to ensure that it had the desired integrity?	___	___	___
13. Were the electrical-continuity connections to the structure made in accordance with the specifications and/or engineering drawings?	___	___	___

	YES	NO	N/A
14. What material(s) or coating(s) was applied to the exposed metal where the copper conductors for the electrical-continuity bonds were attached to the structure and did it meet the requirements of the specifications and/or engineering drawings?			
Coating or Material Applied: ________ ______________________			
15. Was a nonmetallic, weld cap (e.g., bar ·ill shield) installed at each of the locations where a copper conductor fo. . . electrical-continuity bond was attached to the structure?	___	___	___
16. Did the coating repair at the locations of the copper conductor attachments to the structure satisfy the requirements of the specifications and engineering drawings?	___	___	___

1.3 Electrical Isolation

It is important that the structure to be cathodically protected be electrically isolated from other underground or submerged metallic structures that might exist in the general area. Otherwise, the shorted structure(s) will receive some of the protective current and the intended structure may not be adequately protected by the sacrificial anodes. For example, shorted flanges often allow underground gas and water lines to become electrically continuous with the casings or conduits on underground, heat distribution systems, which, in turn, adversely affects the cathodic protection of the casings or conduits.

Figure A2 shows a typical method (i.e., an isolating flange) for electrically isolating one metallic pipe system from another.

With regards to electrical isolation, the inspector should record answers to the following questions:

	YES	NO	N/A
1. Was electrical isolation of the structure to be cathodically protected required by the specifications and/or engineering drawings?	___	___	___
If the answer is "no," no additional questions need to be answered in Section 1.3, Proceed to Section 1.4.			
2. If electrical isolation was required, was the specified device installed at each of the locations identified in the specifications and/or engineering drawings?	___	___	___
3. Was a test(s) conducted to ensure that electrical isolation had been achieved at each of the designated locations and what was the test and the test results?	___	___	___
Test and Test Results: ________________________ ________			
(If required, continue on a separate page)			

1.4 Components/Materials Delivered to the Job Site

With regards to the components and materials delivered to the job site, the inspector should record answers to the following questions:

		YES	NO	N/A
1.	Was a sufficient number of sacrificial anodes delivered to the job site to satisfy the requirements of the specifications and/or engineering drawings?	___	___	___
	Number of Anodes Delivered: ______________			
2.	Were the anodes prepackaged in a water-absorbing, special backfill?	___	___	___
3.	What was the weight of a representative anode and its associated, special backfill?			
	Weight of Anode: ______________			
	Weight of Backfill: ______________			
4.	What was the representative anode-to-soil potential relative to a copper-copper sulfate electrode?			
	Anode Potential, Volt: ______________			
5.	Based upon the anode-to-water potential, was the anode high-potential magnesium, standard-potential magnesium, or high-purity zinc? In this regard, high-potential magnesium, standard-potential magnesium, and high-purity zinc should have potentials of -1.6 to -1.7, -1.5 to -1.6, and -1.05 to -1.1 volts relative to copper-copper sulfate.			
	High-Potential Magnesium: ______________			
	Standard-Potential Magnesium: ______________			
	High-Purity Zinc: ______________			
6.	Using the information presented in Tables A2 and A3 and the certified chemical analysis reports furnished by the anode manufacturer or supplier, did the anodes satisfy the chemical composition requirements of the specifications and/or engineering drawings?	___	___	___
7.	Was the weight of the representative anode within ±10 percent of that for the anode specified in the specifications and/or engineering drawings? (For example, a 17-lb, prepackaged, standard-potential, magnesium anode having a diameter of 4.5 in. and a length of 18 in. should weigh 17 ±1.7 lb (Table A4.) This check may be impractical to perform if installing a small number of anodes.	___	___	___
8.	Was the weight of the backfill surrounding the representative anode within ±10 percent of that for the anode specified in the specifications and/or engineering drawings? (For example, the backfill surrounding a 17-lb, prepackaged, standard-potential, magnesium anode having a diameter of 4.5 in. and a length of 18 in. should weigh 28 ± 2.8 lb; see Table A4.) This check may be impractical to perform if installing a small number of anodes.	___	___	___

NOTE: Additional information on anodes is included in Tables A5, A6, and A7.

		YES	NO	N/A
9.	Was there reason to believe (e.g., the submittal of a certified report from the anode manufacturer or supplier) that the backfill surrounding the anodes was of the type required by the specifications and engineering drawings? In this regard, data for Types A, B, C, and D backfills are included in Table A8.	___	___	___
10.	What was the typical length of the insulated-conductors (i.e., the cables) attached to the anodes? Cable Length: ______________________			
11.	Were the anode-cable lengths at least as long as that required by the specifications and/or engineering drawings?	___	___	___
12.	Did the copper conductors on the anode cables have the specified number of strands? Number of Strands: ______________________	___	___	___
13.	What was the diameter of the copper conductor or the diameter of each strand on the anode cables? Using Table A1, what was the conductor size? Diameter of Conductor: ______________________ Diameter of Each Strand: ______________________ Conductor Size: ______________________			
14.	Did the copper conductors on the anode cables have the size required by the specifications and/or engineering drawings?	___	___	___
15.	What was the type and thickness of the insulation for the copper conductors on the anode cables? In this regard, information on cables that are often used during the installation of a CP system is included in Table A9. Insulation Type: ______________________ Insulation Thickness: ______________________			
16.	Was the insulation type and thickness for the anode cables in accordance with the specifications and/or engineering drawings?	___	___	___
17.	Was the required number of test stations delivered to the job site?	___	___	___
18.	Did the test stations have the required number of terminals? In this regard, information on cathodic protection test stations is included in Table A10. Number of Terminals: ______________________	___	___	___
19.	Were the test stations of the type required by the specifications and/or engineering drawings? Type(s) of Test Station: ______________________	___	___	___
20.	Were the insulated cables for the test station connections specified to be color coded?	___	___	___
21.	Were sufficient lengths of the color-coded, insulated cables for the test station connections delivered to the job site?	___	___	___

	YES	NO	N/A

22. What was the copper-conductor size, the insulation thickness, and the insulation type on the cables for the test-station connections?

    Conductor Size: ____________________

    Insulation Thickness: ____________________

    Insulation Type: ____________________

23. Did the conductor size, insulation thickness, and insulation type for the cable to the test station connections satisfy the requirements of the specifications and/or engineering drawings? ___ ___ ___

24. How were the copper conductors for the anodes to be connected to the structure?

    Exothermically Welded: ____________________

    Welded: ____________________

    Brazed: ____________________

    Through the Test Stations: ____________________

    Other; Identify: ____________________

25. If the copper conductors for the anodes were to be exothermically welded to the structure, what was the mold-part number and the weld-metal part number to be used at the job site?

    Mold-Part Number: ____________________

    Weld-Metal Part Number: ____________________

26. Were the mold-part number and the weld-metal part number to be used in attaching the copper conductors for the anodes to the structure in accordance with the manufacturer's recommendations (if available)? ___ ___ ___

27. How were the copper conductors for the test stations to be attached to the structure?

    Exothermically Welded: ____________________

    Welded: ____________________

    Brazed: ____________________

    Other; Identify: ____________________

28. If the copper conductors for the test stations were to be exothermically welded to the structure, what was the mold-part number and the weld-metal part number to be used at the job site?

    Mold-Part Number: ____________________

    Weld-Metal Part Number: ____________________

29. Were the weld-metal part number and the mold-part number to be used in attaching the copper conductors for the test station to the structure in accordance with the manufacturer's recommendations (if available)? ___ ___ ___

30. Were shunts specified to be installed in the test stations (i.e., between the terminal for the structure and the terminal for the anode)? ___ ___ ___

		YES	NO	N/A
31.	Did the shunts delivered to the job site have the specified resistance?	___	___	___
32.	Was the installation of any permanently-installed, reference electrodes required by the specifications and/or engineering drawings?	___	___	___
33.	If permanently-installed, reference electrodes were to be installed, was the required number of these delivered to the job site and did each of these have a potential that was within ±7 millivolts of a calibrated reference electrode of the same type?	___	___	___
34.	What products were delivered to the job site for repairing coating damage on the structure where the copper conductors were to be attached? Coating Products: ______________________			
35.	Were the products to be used for repairing coating damage to the structure at the copper-conductor attachment sites in accordance with the specifications and/or engineering drawings?	___	___	___
36.	Were weld caps (i.e., backfill shields) required by the specifications and/or engineering drawings where copper conductors were to be attached to the structure?	___	___	___
37.	Was a sufficient number of weld caps of the required type delivered to the job site?	___	___	___

1.5 Installation of the Components/Materials

A typical installation where a sacrificial anode is directly connected to an underground pipe is shown in Figure A3. Figure A4 shows a representative installation where a sacrificial anode is connected to an underground pipe through a test station.

With regards to the installation of a sacrificial anode type, CP system, the inspector should record answers to the following questions:

		YES	NO	N/A
1.	Were anodes installed at each of the sites and within ±1 ft of the site locations identified on the engineering drawings?	___	___	___
2.	Were the hole diameters and depths for the anodes within ±10 percent of the dimensions specified on the engineering drawings? Hole Diameter: ______________________ Hole Depth: ______________________	___	___	___
3.	Was the waterproof container for each prepackaged anode removed before the anode was installed?	___	___	___
4.	Were the anodes installed vertically or horizontally? Vertically: ______________________ Horizontally: ______________________			

		YES	NO	N/A
5.	Were any anodes supported by the anode cables when they were lowered into the holes?	___	___	___
6.	Were the cables for the anodes installed at a minimum depth of 18 in. below grade except where they surfaced at a test station?	___	___	___
7.	Did the ancillary cables to the test stations have the proper color coding?	___	___	___
8.	Were the ancillary cables to the test stations installed at a minimum depth of 18 in. below grade except where they surfaced at a test station?	___	___	___
9.	Did the anode cables and the ancillary cables to the test stations have sufficient "slack" (approximately 2 ft in length) such that they would not be broken during backfilling?	___	___	___
10.	If the copper conductors on the anodes and the ancillary cables to the test stations were exothermically welded to the structure, was the proper weld-metal part number and the mold-part number used for the conductor and structure involved?	___	___	___
11.	Did the molds used to make the exothermic welds appear to be excessively worn?	___	___	___
12.	Was each exothermic weld tested for integrity and subsequently cleaned?	___	___	___
13.	Was the coating damage at each copper-conductor attachment site on the structure suitably repaired before backfilling?	___	___	___
14.	If required, were weld caps installed at the copper-conductor attachment sites on the structure?	___	___	___
15.	Was fine soil properly tamped into the annulus between each anode and its respective hole without damage to the anode cable?	___	___	___
16.	Were each of the test stations installed within ±2 ft of the sites identified on the engineering drawings?	___	___	___
17.	Was the specified type of test station installed at each of the sites identified on the engineering drawings?	___	___	___
18.	Were the test stations installed in accordance with the engineering drawings and/or the manufacturers recommendations?	___	___	___
19.	Were the connections in the test stations made in accordance with the engineering drawings?	___	___	___
20.	If required, were the permanently-installed, reference electrodes installed in strict accordance with the engineering drawings?	___	___	___
21.	If the anodes were not prepackaged, was the backfill installed in strict accordance with the engineering drawings?	___	___	___
22.	If the anodes were to be installed without backfill, were they installed in strict accordance with the engineering drawings?	___	___	___
23.	Was the construction area returned to its natural status after the CP system was installed?	___	___	___

1.6 Commissioning the Cathodic Protection System

With regards to commissioning the CP system, it normally takes some time for polarization to take place on the structure surface depending on coating condition and electrolyte resistivity. Structure-to-environment potential and anode current output measurements should be made after electrical connection of the anode to the structure. If the structure to electrolyte potentials do not meet the criteria of protection, a record survey should be conducted after a 2-month interval to allow for polarization of the structure to occur.

During commissioning of the CP system, the inspector should record answers to the following questions:

	YES	NO	N/A
1. Was a structure-to-environment potential survey conducted after the CP system had been installed at least 2 months?	___	___	___
2. If a structure-to-environment potential survey was conducted, record the results on a separate sheet(s) of paper using the following format:			

Test Location	Structure-to-Environment Potential, Volt*

*Identify the reference electrode used on the data sheet(s).

Alternatively, the structure-to-environment potentials may be placed on a graph or a drawing of the structure.

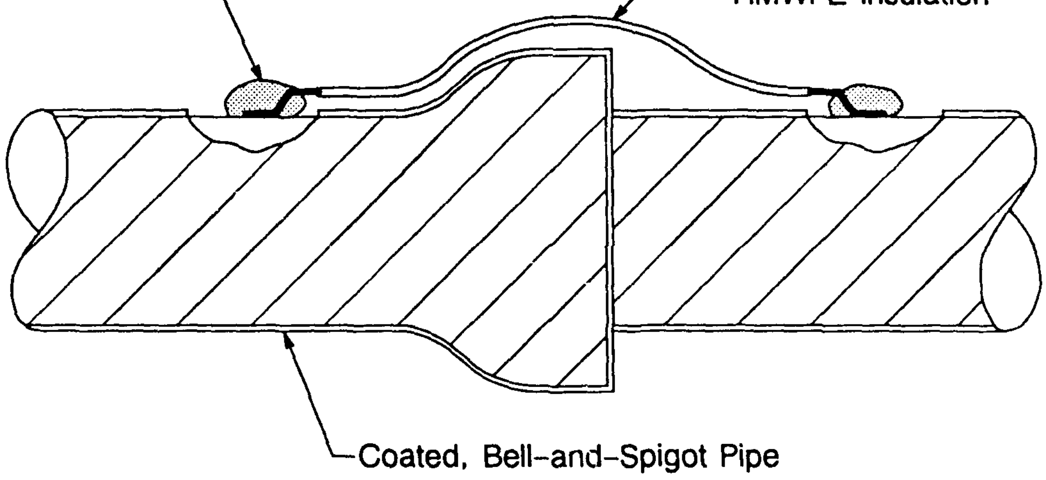
	YES	NO	N/A
3. Did the results of the structure-to-environment potential survey reveal that adequate corrosion mitigation had been achieved, according to at least one of the National Association of Corrosion Engineers Criteria for Cathodic Protection? For example, if the protected structure was steel, cast iron, ductile iron, or stainless steel, was it polarized to at least -0.85 volt and no more than -1.3 volts relative to a copper-copper sulfate reference electrode at all locations? Alternatively, was the ferrous-base material polarized in the negative direction at least 100 millivolts and no more than 500 millivolts at all locations with regards to the natural, structure-to-environment potentials at these locations?	___	___	___
4. Were the anode current outputs measured at the test stations?	___	___	___
5. If the anode current outputs were measured at the test stations, record these data on a separate sheet(s) of paper using the format:			

Location of Test Station	Anode Current Output*

* Include units (e.g., milliamperes) on data sheet.

	YES	NO	N/A
6. If two ancillary cables were connected to the structure at a test station, did both of these give the same results when measuring the anode current output and the structure-to-environment potential?	___	___	___
7. Was there any reason to believe that any of the cables to either the structure or the anode had been broken during the backfilling?	___	___	___
8. If broken cables existed at any of the test stations, were these suitably repaired?	___	___	___

	YES	NO	N/A
9. If the CP system involved an underground pipe system where the pipe was cased (e.g., at a road or railroad crossing), were tests conducted to ensure that the casing was not shorted to the pipe?	___	___	___



Notes: 1. After welding and "hammer testing" the weld, all exposed metal must be recoated.

2. Leave "slack" in bond wire.

Figure A1. Method for Obtaining Electrical Continuity at High Resistance/Insulated Connection.

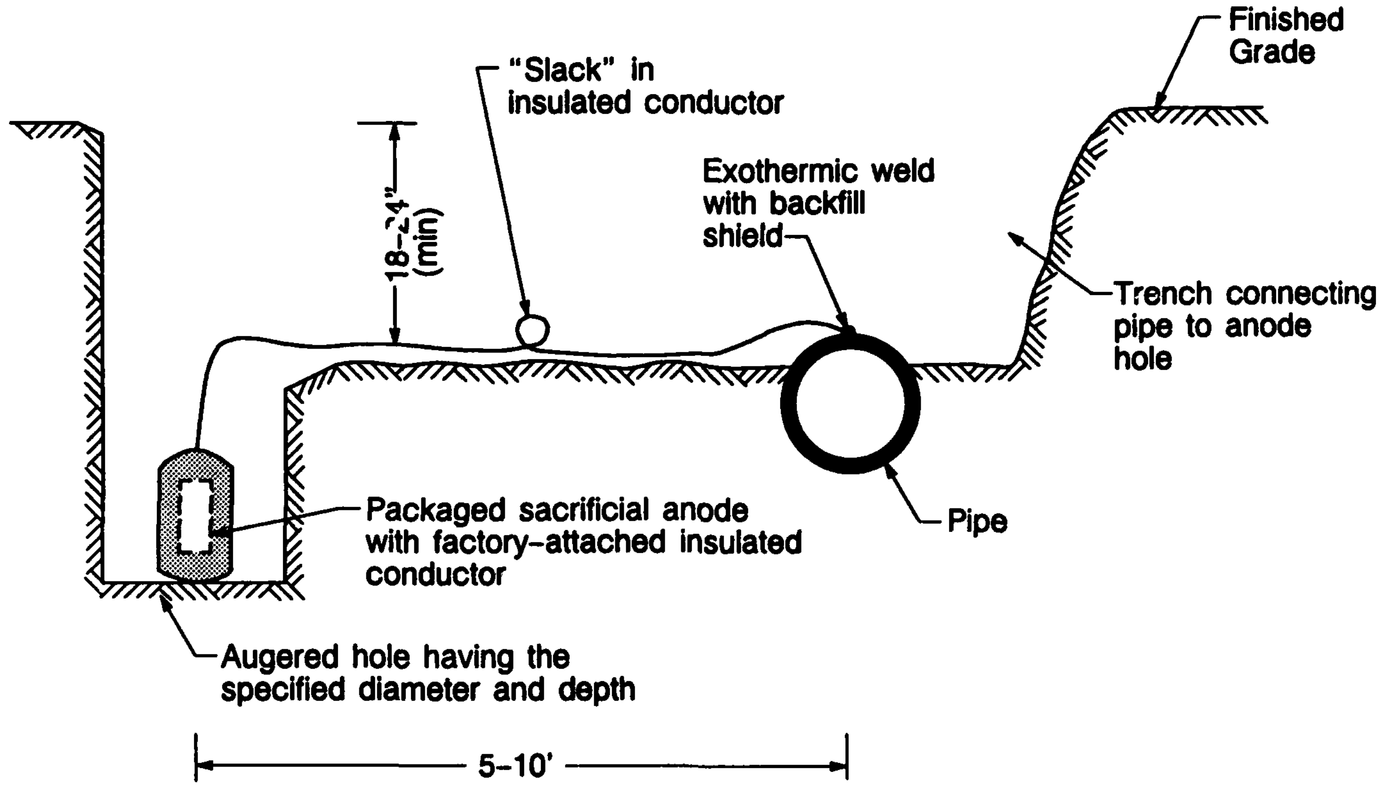


Figure A2. **Cross-Section, Before Backfilling, of a Packaged, Vertically-Positioned, Sacrificial Anode Installation in Soil Where the Anode is Directly Connected to the Pipe.**

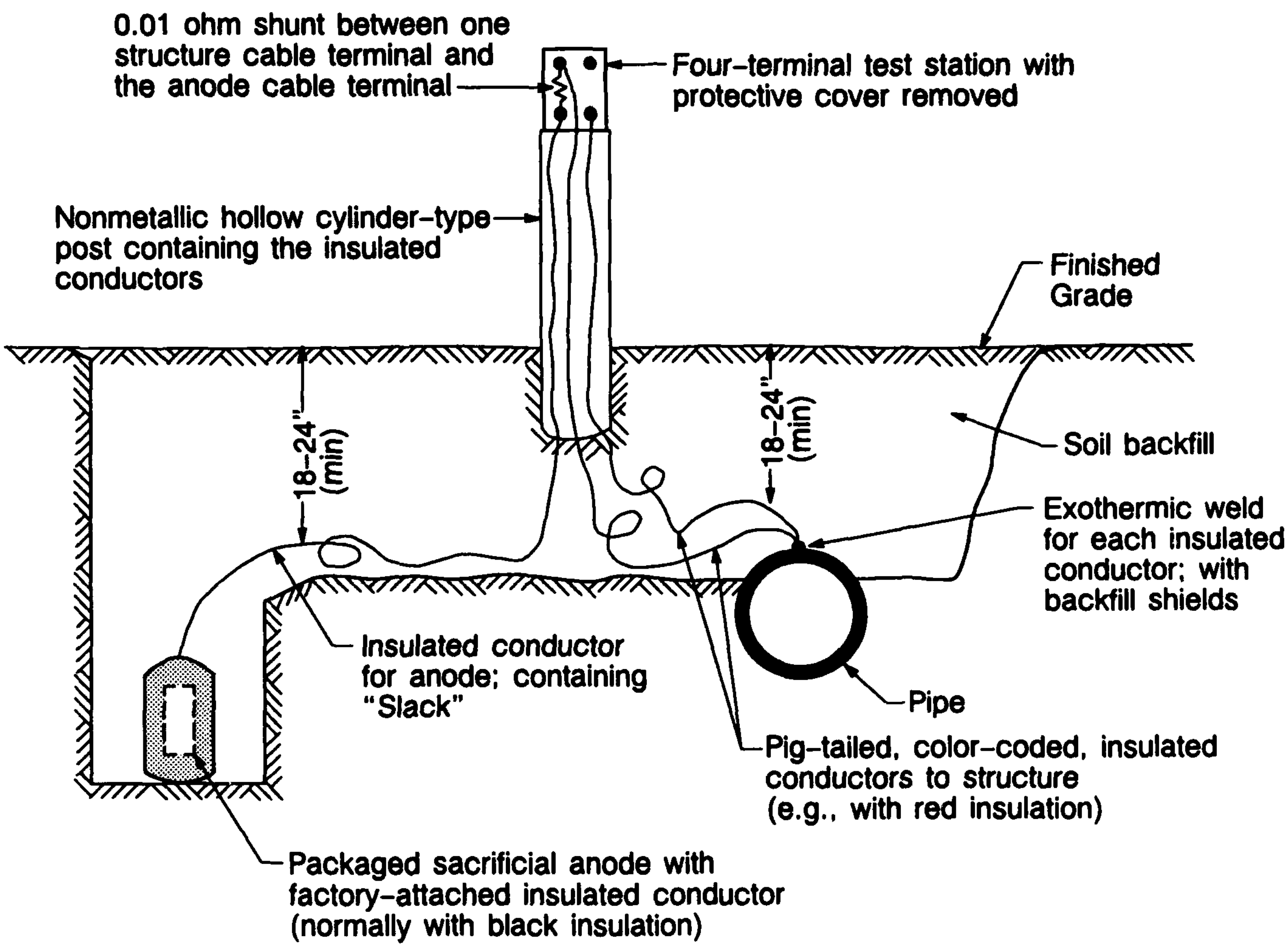
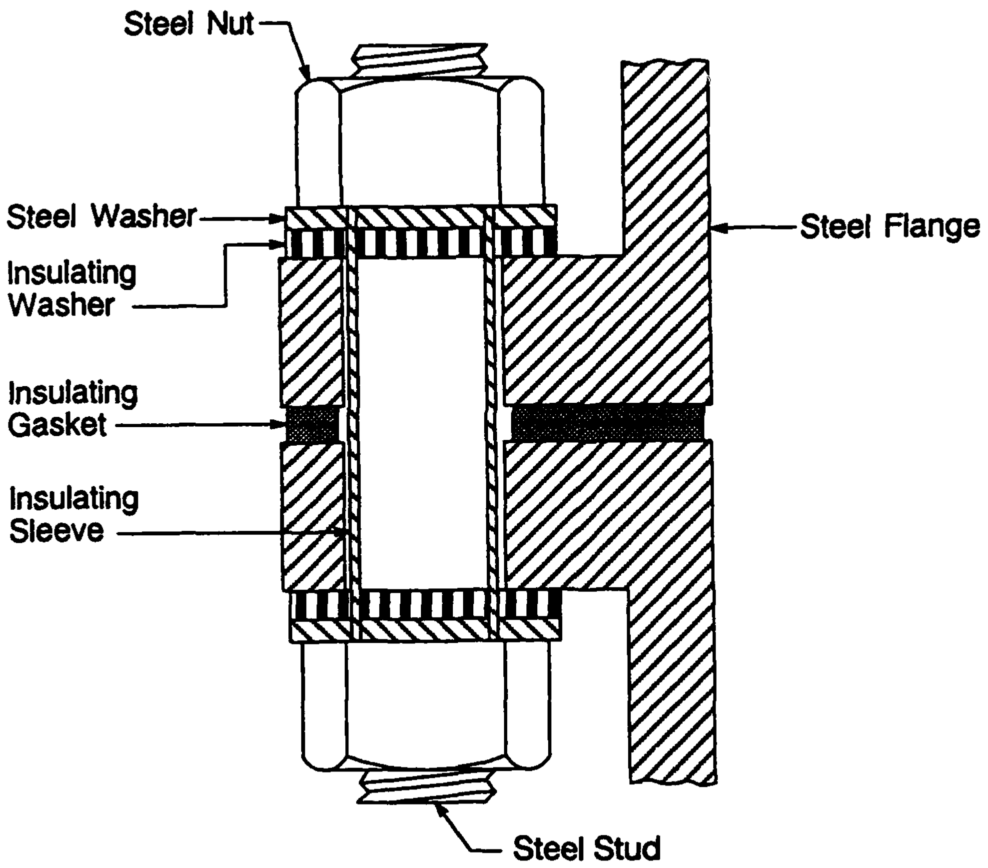


Figure A3. **Cross Section, After Backfilling, of a Packaged, Vertically-Positioned, Sacrificial Anode in Soil Where the Anode Is Connected to a Pipe Through a Test Station.**



Note: Nonmetallic integral sleeve and washer may be used to replace the insulating sleeve and one insulating washer.

Figure A4. Method for Obtaining Electrical Isolation at a Flanged Connection.

Table A1

Diameters for Concentric-Lay Stranded and Solid Standard Annealed Copper Conductors

Conductor Size (AWG/MCM)	Diameter, Solid Conductor, in.*	Diameter, Stranded Conductor, in.*
350(2)	-	0.681
300(2)	-	0.630
250(2)	-	0.575
4/0	0.460	0.528
3/0	0.4096	0.470
2/0	0.3648	0.418
0	0.3249	0.373
1	0.2893	0.332
2	0.2576	0.292
3	0.2294	0.260
4	0.2043	0.232
6	0.1620	0.184
8	0.1285	0.146
10	0.1019	0.116
12	0.0808	0.092
14	0.0641	0.073

* Without Insulation.
* Thousands of Circular Mils (MCM).

Table A2

Chemical Compositions for Magnesium-Alloy Anodes Used in Soil and Water

	Weight Percent, w/o			
Constituent	Std. Potential, Grade A	Std. Potential, Grade B	Std. Potential, Grade C	High Potential
Aluminum	5.3-6.7	5.3-6.7	5.0-7.0	0.010**
Manganese*	0.15*	0.15*	0.15*	0.5-1.30****
Zinc	2.5-3.5	2.5-3.5	2.0-4.0	0
Silicon**	0.10**	0.30**	0.30**	0
Copper**	0.02**	0.05**	0.10**	0.02**
Nickel**	0.002**	0.003**	0.003**	0.001**
Iron**	0.003**	0.003**	0.003**	0.03**
Other	0.30**	0.30**	0.30**	—
Magnesium	Balance	Balance	Balance	Balance

* Minimum Amount Allowable.
** Maximum Amount Allowable.
*** 0.05 percent Maximum of Each; Total Maximum of 0.03 percent.
**** In the range 0.5 to 0.8 percent, Manganese is at least 0.5 + 60(percent Aluminum).

Table A3

Chemical Composition for High-Purity Zinc Anodes Used in Soil and Fresh Water*

Constituent	Weight Percent
Aluminum	0.005 (max.)
Cadmium	0.003 (max.)
Iron	0.0014 (max.)
Lead	0.003 (max.)
Zinc	Balance

* Anodes produced in accordance with American Society for testing and Materials (ASTM) Standard Specification B418, Type II.

Table A4

Standard-Size, Standard-Potential, Magnesium-Alloy Anodes for Use in Soil

Anode Weight (lb)	Anode Size (in.)*,**	Packaged Wt. (lb)*	Packaged Size (in.)*,**	Backfill Wt. (lb)*
3	2.7 × 9	12	5.5 × 11.5	9
5	3.1 × 9	17	5.0 × 15	12
9	3.5 × 14	27	6.0 × 24	18
17	4.5 × 18	45	7.5 × 26	28
32	5.5 × 22	72	8.0 × 27	40
50	7.5 × 18	100	10.0 × 26	50

* Anode sizes as well as the packaged weights, packaged sizes, and backfill weights can be expected to vary slightly depending upon the anode manufacturer.

** This measurement is given as diameter × length.

Table A5

Standard-Potential, Magnesium-Alloy Anodes for Use in Water*

Anode Weight, lbs	Anode Size, in.
20	3.5 × 3.5 × 26
50	7 × 7 × 16
50	8 (dia.) × 16
100	7 × 7 × 32
15**	4 × 8 × 8
24**	2 × 9 × 18
44**	4 × 9 × 18
60**	7 × 9 × 18
0.36/ft***	0.75 (dia.) × 1-20 ft.
0.45/ft***	0.84 (dia.) × 1-20 ft.
0.68/ft***	1.05 (dia.) × 1-20 ft.
1.06/ft***	1.32 (dia.) × 1-20 ft.
1.50/ft***	1.56 (dia.) × 1-20 ft.
2.50/ft***	2.02 (dia.) × 1-20 ft.

* Anodes are not packaged for use in water.
** Commonly used in condensers and heat exchangers.
*** Commonly used in water tanks and water heaters.

Table A6

Standard-Size, High-Potential, Magnesium-Alloy Anodes for Use in Soil

Anode Weight (lb)	Anode Size (in.)*	Packaged Wt. (lb)*	Packaged Size (in.)*,**	Backfill Wt. (lb)*
3	3.7 × 3.7 × 5	12	6 × 10	9
5	3.7 × 3.7 × 7.5	17	6 × 12	12
9	2.7 × 2.7 × 26	35	6 × 31	26
9	3.7 × 3.7 × 13	27	6 × 17	18
14	2.7 × 2.7 × 41	50	6 × 46	36
14	3.7 × 3.7 × 21	42	6.5 × 26	28
17	3.7 × 3.7 × 26	45	6.5 × 29	28
17	2.7 × 2.7 × 50	60	6 × 55	43
24	4.5 × 4.5 × 23	60	7 × 30	36
32	5.5 × 5.5 × 21	74	8 × 28	42
32	3.7 × 3.7 × 47	91	6.5 × 53	59
40	3.7 × 3.7 × 59	105	6.5 × 66	65
48	5.5 × 5.5 × 30	100	8 × 38	52

* Anode sizes as well as the packaged weights, packaged sizes, and backfill weights can be expected to vary slightly depending upon the anode manufacturer.
** This measurement is given as diameter × length.

Table A7

High-Purity Zinc Anodes for Use in Soil and Fresh Water*

Anode Weight (lb)	Anode Size (in.)
5	1.4 × 1.4 × 9
18	1.4 × 1.4 × 36
27	1.4 × 1.4 × 48
30	1.4 × 1.4 × 60
30	2 × 2 × 30
50	2 × 2 × 48
60	2 × 2 × 60
2.3/in	3 × 3 × 6-60
4.2/in	4 × 4 × 6-60
6.5/in	5 × 5 × 6-43
12.8/in	7 × 7 × 6-36
21/in	9 × 9 × 12-24
26/in	10 × 10 × 9-24
2.50/ft[3]	2.02 (dia.) × 1-20 ft

* For soil installation, the anodes must be backfilled.

Table A8

Special Backfills for Sacrificial Anodes

	Constituent, weight percent				
Type	Hydrated $CaSO_4$	Calcined $CaSO_4$	Bentonite Clay	Na_2SO_4	Approx. Resistivity ohm*cm
A*	25	-	75	-	250
B**	50	-	50	-	250
C***	-	50	50	-	250
D****	75	-	20	5	50

* Often specified for areas of low soil moistures
** Commonly specified for zinc anodes
*** Often specified for zinc and magnesium-alloy anodes in very wet soils and marshy areas
**** Often specified for higher resistivity soils in order to reduce the resistance

Table A9

Insulation Thickness for Stranded and Solid Copper Conductors

Insulation Type	Conductor Size (AWG/MCM)	Insulation Thickness (in.)
Thermoplasitc	10-14	0.030
Waterproof	8	0.045
(TW)	6-2	0.060
	1-4/0	0.080
	213-500*	0.095
High Molecular Wt.		
Polyethylene (HMWPE)	2-8	0.110
	1-4/0	0.125
	250*	0.155
Dual		
ECTFE** or PVF***	-	0.020
Primary	-	0.065
HMWPE Secondary		

* Thousands of circular mils (MCM).
** Ethylene monochlorotrifluorethylene.
*** Polyvinylidene Flouride.Note: For dual insulation, the primary is the inner insulation; secondary is the outer insulation.

Table A10

Terminal Requirements for Cathodic Protection Test Stations Associated With Underground Structures

Purpose of Test Station	Minimum Number of Terminals
Structure-to-environment potential testing	2
Insulated joint testing	4
4-Lead calibrated pipeline current testing	4
Combination insulated joint and pipeline	
Current testing	6
Testing of crossings with "foreign" pipelines	4
Sacrificial-anode testing	3
Testing of pipelines at cased crossings	
a. Casings with vents	3
b. Casings without vents	4